INFLUENCE OF E-BEAM POSTHARVEST IRRADIATION IN THE COLOUR OF FOUR EUROPEAN CHESTNUT FRUIT VARIETIES OF *CASTANEA SATIVA* MILL

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Abstract:

In this study we characterized the physical dimensions of four European chestnut varieties of *Castanea sativa*, 3 from Portugal (*Cota*, *Longal* and *Judia*) and 1 from Italy (*Palummina*). The typical physical dimensions of the different chestnut fruit varieties could be used to optimize the process in an irradiation preservation treatment. The chestnut fruits were submitted to an irradiation preservation treatmen with electron beam, at 1 kGy, and the colour parameters (CIE L*, a*, b*) of the skins, fruit and interior (half-cutted), were monitored after irradiation treatment and along 2 months of storage. We could conclude that e-beam irradiation, for the dose of 1 kilogray, did not induce any significant change in the skin, fruit and interior's colour parameters.

Key Words: Chestnuts, *Castanea sativa* Mill., e-beam irradiation, physical parameters, colour

Introduction

In the Mediterranean countries the production of chestnut fruits is about 200 000 ton, being Portugal the third producer of Castanea sativa Mill varieties, with about 30 000 ton, exporting 10 000 ton, representing an income of about 14 million Euros (FAOSTAT, 2010; INE 2010). Due to phytosanitary regulations the exported fruits must be postharvest treated. Until recently, March 2010, this was done with methyl bromide (MeBr) for postharvest fumigation, now prohibited by E.U. regulations due to its toxicity for the operators and environmental concerns. Food irradiation is a well-established technology, regulated by several directives and approved by the international food and safety organizations for preservation or insect disinfestations, using gamma radiation, electron beam or x-rays (EU, 1999; FAO/IAEA/WHO, 1981). The typical dose for postharvest insects' disinfestations is lower than 1 kGy (IDIDAS, 2013). However, each irradiation process must be validated to meet the needed food quality parameters. Due to the limitation of electron penetration for e-beam irradiation, the dimensions are an important issue in the design of the process that imposes limitations in using this technology, since the authorized energy for e-beam food processing is limited to 10 MeV. Also, the throughput of the process is limited by the dimensions of the fruit. From the market point of view, the dimensions and colour are two main parameters valued by the consumer. The effect of e-beam radiation on nutritional parameters of irradiated chestnut fruits are also under validation by our research group (Carocho et al., 2012). Previous studies on chestnut fruits preservation by irradiation were done in Asian varieties and only recently in European varieties, mainly using gamma radiation (Antonio et al., 2012). Here we have studied the effect of e-beam irradiation on the colour parameters of four European chestnut fruit varieties, from Portugal and Italy.

Materials and Methods

Samples

European chestnut fruits (*Castanea sativa* Miller) of varieties "*Longal*", "*Judia*" and "*Cota*", harvested in October 2012, were obtained from local producers in the Northeast of Portugal. The Italian chestnuts, from a selected variety "*Palummina*", were obtained in a local market in Naples, Italy, in October 2012. The fruits were divided in two groups, control and irradiated, weighing approximately 0.5, kg to be exposed to the radiation dose of 1 kGy - considering 0 kGy the non-irradiated, control sample. After irradiation, the samples were stored at 4 ºC and the colour parameters monitored immediately after irradiation and at fixed intervals of 30 days of storage,

Irradiation

The irradiation with electrons was performed at the INCT –Institute of Nuclear Chemistry and Technology – in Warsaw, Poland, with an e-beam of 10 MeV of energy. A pulse duration of 5.5 μs, pulse frequency of 440 Hz, average beam current of 1.1 mA, a scan width of 68 cm, conveyer speed in the range 20-100 cm/min and a scan frequency of 5 Hz. The absorbed dose was 1 kGy, with an uncertainty of 4%. To estimate the dose, routine dosimeters, Amber Perspex and Gammachrome YR dosimeters (from Harwell Company, U.K.) and a standard dosimeter, Graphite Calorimeter, were used (IAEA, 2002).

Physical Parameters - Dimensions

The axial dimensions of the fruits were determined measuring the length (L), width (W) and thickness (T) of eighteen chestnut fruits, using a digital calliper with a precision of 0.01 mm. The arithmetic and geometric diameters, as well as the sphericity, were calculated using the equations (1), (2) and (3) (Mohsenin, 1986).

Arithmetic diameter: $Da = (L + W + T) / 3$ (1)

Geometric diameter $Dg = (L \times W \times T)^{1/3}$ (2)

Sphericity $\Phi = (L \times W \times T)^{1/3} / (\max [L,W,T])$ (3)

Physical Parameters - Colour

For colour determination, the CIE L*, a*, b* scale was used, measuring the colour parameters with a colorimeter (CR400, from Konica Minolta, Japan), calibrated with a white tile, using C illuminant and a diaphragm aperture of 8 mm. The measurements were made on the skin, fruit (after hand peeling) and fruits interior (after cutting the fruits in two halves). The colour of nine chestnuts was measured in three different points, for each dose (0 and 1 kGy), n = 27, and at each time point (0, 30 and 60 days of storage), n = 54.

Results and discussion

Physical characteristics

The axial dimensions and mass of irradiated chestnut fruits are presented in Table 1.

Table 1 - Physical characteristics of chestnut fruits, *Castanea sativa* Mill.: mass (m), width (W), length (L), thickness (T).

	m (g)	W (mm)	L (mm)	T (mm)
Longal	12.17 ± 1.26	31.36 ± 1.41	36.77 ± 1.29	18.41 ± 2.07
Judia	16.92 ± 2.79	36.30 ± 2.41	35.82 ± 2.58	22.79 ± 3.04
Cota	14.65 ± 2.52	34.43 ± 2.57	35.91 ± 1.66	20.61 ± 3.18
Palummina	18.94 ± 3.55	36.84 ± 3.16	35.88 ± 1.94	25.95 ± 3.99

The results are expressed as mean ± std. dev (n = 18).

The four chestnut fruit varieties present similar lengths and similar widths, except for the *Longal* variety with a lower width. The lower thickness and mass is presented by the *Longal* variety and the biggest thickness and mass by the *Palummina* variety (Fig. 1).

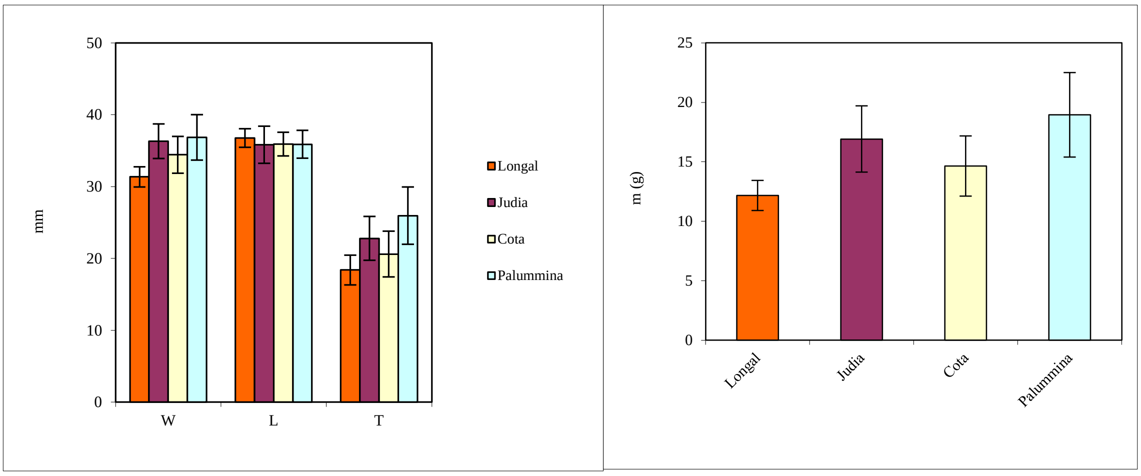

Fig.1. Dimensions and mass of four chestnut fruit varieties of *Castanea sativa* Mill.

Regarding arithmetic diameter, geometric diameter and sphericity, the lower values are presented by the *Longal* variety and the higher values by the *Palummina* variety, showing that the first were almost planar and the last almost round (Table 2).

Table 2 - Physical characteristics of chestnut fruits, *Castanea sativa* Mill.: arithmetic diameter (D_a), geometric diameter (D_g,) and sphericity (Φ).

	D_a (mm)	D_g (mm)	Φ
Longal	28.85 ± 0.95	27.64 ± 1.16	0.75 ± 0.03
Judia	31.64 ± 1.81	30.87 ± 1.96	0.83 ± 0.04
Cota	30.32 ± 1.70	29.34 ± 1.98	0.80 ± 0.04
Palummina	32.89 ± 1.76	32.37 ± 2.00	0.88 ± 0.07

The results are expressed as mean ± std. dev (n = 18).

Colour

The colour parameters L*, a* and b* were measured for the non-irradiated (0 kGy) and irradiated (1 kGy) at 0, 30 and 60 days of storage at 4 ^{o}C. Here we present only the results for L* and b*, since for the skins a* parameter follows the same tendency. And for the fruit and interior this value is close to zero (data not shown).

Chestnut skins present lower values for L* ("lightness") and b* ("redness-yellowness") than fruits and interior (Fig. 2).

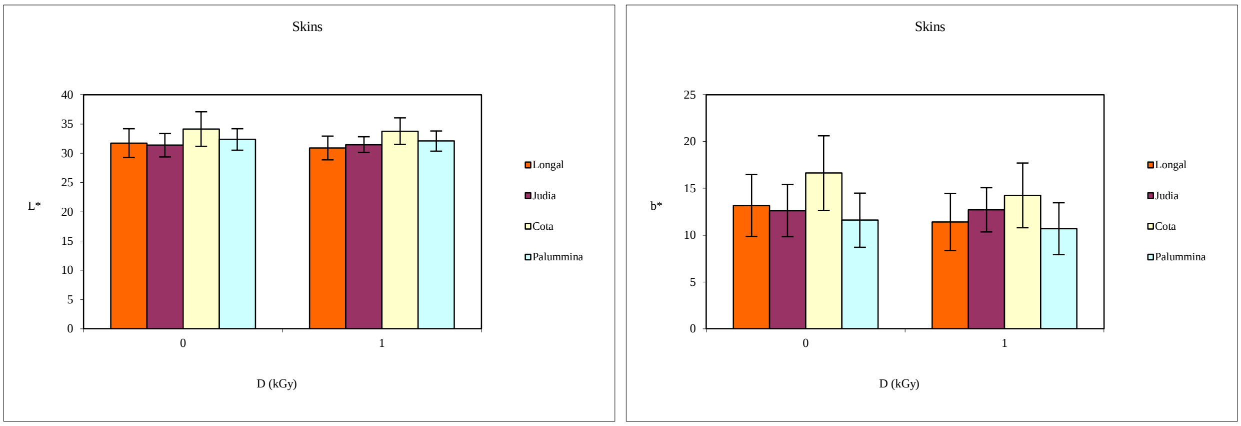

Fig. 2. Skins colour (L* - , b* - value) of four varieties of *Castanea sativa* Mill.

The higher value for L* was registered for the interior (half-cut) and the higher value for b* ("yellowness") was displayed by the peeled fruits (Fig. 3 and Fig. 4).

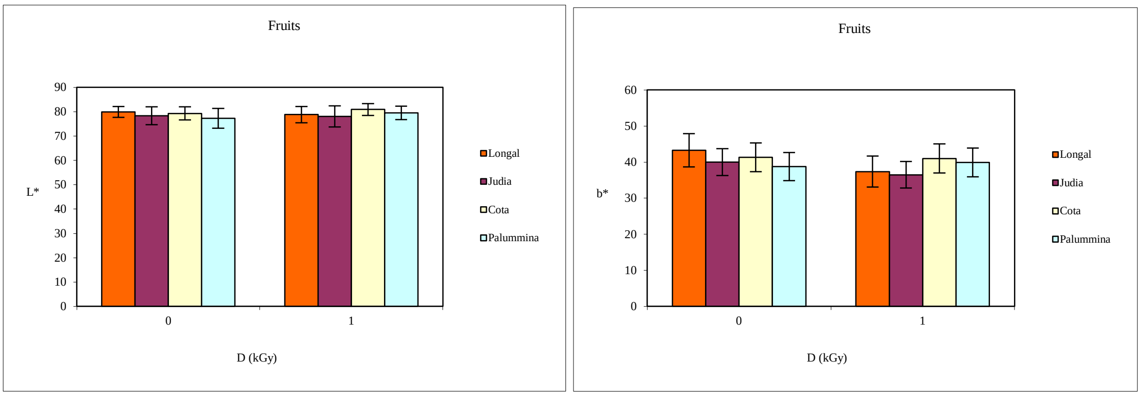

Fig. 3. Fruits colour (L* - , b* - value) of four varieties of *Castanea sativa* Mill.

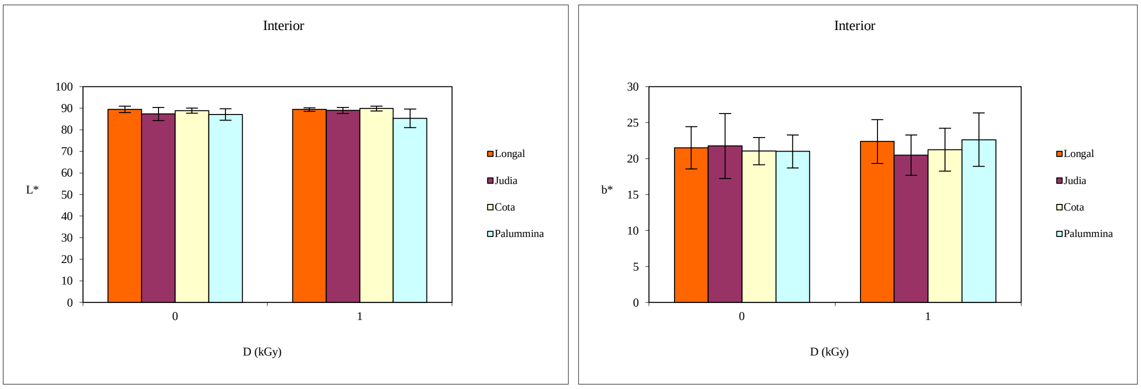

Fig. 4. Fruits interior colour (L* - , b* - value) of four varieties of *Castanea sativa* Mill.

From the results, we could also see that chestnut varieties present similar values for L* and b*, for skins, fruit and interior (half-cut), for non-irradiated and irradiated fruits (Fig. 2 - 4).

According to these results (Fig.2-4), L* and b* parameters showed similar values. We have followed these parameters along storage time (Fig. 5), concluding that non-irradiated and irradiated samples present similar results at each time point. With storage time, b*-value ("yellowness") showed an increasing tendency for irradiated and non-irradiated samples, represented in the graphs by the dashed line

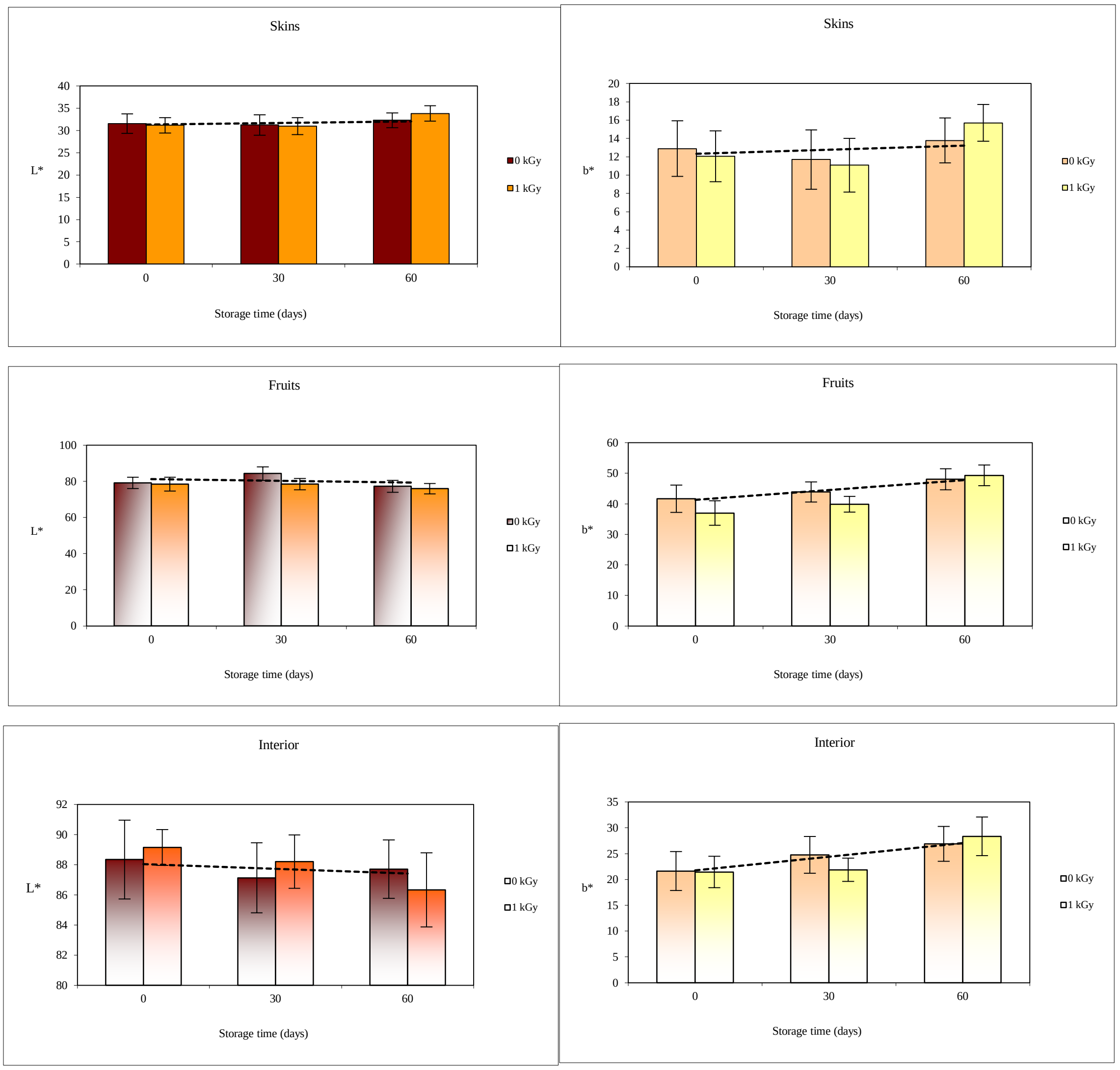

Fig. 5. Chestnuts colour of *Castanea sativa* Mill. along storage time.

Conclusion

There's a tendency in the agro-industrial units that processes these fruits to separate the chestnuts by varieties, due to their different size value in the market. In an irradiation preservation treatment, the typical physical dimensions of the different varieties could be used to optimize the irradiation process, the throughput and e-beam penetration. Up to the applied dose of 1 kilogray and 60 days of storage, e-beam irradiation did not induce any significant change in the skins, fruits and interior colour on the four chestnut fruit varieties. Since the typical dose for insect disinfestations is lower than 1 kGy, we can conclude that e-beam postharvest irradiation could be a promising alternative to the banned MeBr fumigation.

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References:

Antonio, A. L. et al, 2012. "Effects of gamma radiation on the biological, physico-chemical, nutritional and antioxidant parameters of chestnuts - A review". Food and Chemical Toxicology 50, 3234-3242.

Carocho, M., Barreira, J.C.M., Antonio, A.L., Bento, A., Kaluska, I., Ferreira, I.C.F.R., 2012. "Effects of Electron-Beam Radiation on Nutritional Parameters of Portuguese Chestnuts (Castanea sativa Mill.)". J. Agricultural Food Chemistry 60, 7754−7760.
EU, 1999. Directive 1999/2/EC: On the approximation of the laws of the Member States concerning foods and food ingredients treated with ionising radiation. Official Journal of the European Communities L 66/16, 13th March.
EU, 2008. "Commission Decision, 753/2008". Official Journal of the European Union L 258/68, 26th September.
FAOSTAT, 2010. Food and Agriculture Organization of the United Nations. Available from: http://faostat.fao.org/site/339/default.aspx . Accessed March 2013.
FAO/IAEA/WHO, 1981. Wholesomeness of irradiated food. Report of a Joint FAO/IAEA/WHO Expert Committee. Technical Report Series, 659, World Health Organization, Geneve, Switzerland.
IAEA, 2002. Dosimetry for food irradiation. Technical report series 409, International Atomic Energy Agency, Vienna, Austria, ISSN 0074–1914.
IDIDAS, 2013. International Database on Insect Disinfestation and Sterilization Available from: http://nucleus.iaea.org/ididas/ . Accessed March 2013.
INE, 2010. Portuguese Agricultural Statistics. Instituto Nacional de Estatística I.P., Lisbon, Portugal. Available from: http://www.ine.pt . Accessed March 2013.
Mohsenin N. N. (1986). Physical properties of plant and animal materials. Gordon and Breach Sci. Publishers, New York, USA.